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ABSTRACT

The effects of visual grouping strategies involving animated and static graphic presentations on learning were studied. Also studied was the ability of students to learn a scientific rule presented incidentally in an animated sequence in the hope of replicating results from previous research. A total of 39 fourth graders participated in an introductory lesson on Newton's laws of motion. Two levels of Visual Presentation (Static Graphic, Animated Graphic) were crossed with two levels of Visual Grouping (Grouped, Ungrouped). A within-subjects factor consisted of two levels of Learning Intent (Intentional, Incidental). Results showed that students given animated presentations of lesson content outperformed students receiving static presentations, but only when the animated lesson frames were presented in groups, or "chunks," of textual and visual sequences. These results demonstrate how students' selective attention toward information contained in animated visuals can be undermined when the presentation insufficiently cues their focus of attention to the animated sequence. These results also illustrate at least one possible strategy which can be used to improve the ability of students to attend to and learn from animated visuals. Results also showed that students were successfully able to extract information pertaining to an application of Newton's second law incidentally presented in animated sequences. These results successfully replicate earlier findings indicating that elementary school students can learn and apply incidental information from an animated display without necessarily sacrificing intentional learning. (21 references) (Author/BBM)

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The Effects of Visual Grouping on Learning from Computer Animated Presentations

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Abstract

The effects of visual grouping strategies involving animated and static graphic presentations on learning were studied. Also studied was the ability of students to learn a scientific rule presented incidentally in an animated sequence in the hope of replicating results from previous research. A total of 39 fourth graders participated in an introductory lesson on Newton's laws of motion. Two levels of Visual Presentation (Static Graphic, Animated Graphic) were crossed with two levels of Visual Grouping (Grouped, Ungrouped). A within-subjects factor consisted of two levels of Learning Intent (Intentional, Incidental). Results showed that students given animated presentations of lesson content outperformed students receiving static presentations, but only when the animated lesson frames were presented in groups, or "chunks," of textual and visual sequences. These results demonstrate how students' selective attention toward information contained in animated visual can be undermined when the presentation insufficiently cues their focus of attention to the animated sequence. These results also illustrate at least one possible strategy which can be used to improve the ability of students to attend to and learn from animated visuals. Results also showed that students were successfully able to extract information pertaining to an application of Newton's second law incidentally presented in animated sequences. These results successfully replicate earlier findings indicating that elementary school students can learn and apply incidental information from an animated display without necessarily sacrificing intentional learning.

Dramatic visual effects can be produced with computer animation. Intuition would suggest that learning from apparently well-designed animated displays would be equally dramatic. Unfortunately, research has not shown this to be the case. It appears that animated instruction, even in its best form, exerts a relatively subtle influence on learning and that many factors can serve to undermine its effectiveness (see review by Rieber, 1990-a). For example, students may have difficulty attending to relevant details contained in animated visual displays which may be obvious to the designer or an expert (Reed, 1985; White, 1984). However, several very recent reports have begun to clarify some of the conditions under which animation may facilitate learning (Rieber, 1990-b; Rieber, in press).

An example of the evasive nature of animation's effect on learning is provided by Rieber (1989) who reported no significant differences on the learning of science concepts between animated and static visual presentations. However, the elementary school subjects took significantly less *time* to process lesson frames containing the animated sequences than similar frames containing static graphics or all text. It was speculated that students did not effectively attend to the animation or may have been distracted by the combination of visual and verbal information presented to them. An even more likely hypothesis is that students used the time needed to display the animation for other mental tasks, such as reading screen text, thereby obviating any benefit to learning which the animation might have provided. From a theoretical perspective, this is the problem of selective attention (Woolfolk, 1987). Animation is probably an effective attention-gaining device, especially for brief periods, but when animation is designed to be informational or instructive, learning demands sustained meaningful effort on the part of students. Students must be able to perceive important information and also actively select and process this information in the proper context. This is especially important given the temporal nature of animation — students may not have a second chance to view the sequence once it has ended.

The Rieber (1989) study was replicated with a variety of changes to the lesson's instructional design. One such change involved modifying the way in which the lesson frames were presented to students. Instead of presenting frames one at a time, as conventional design wisdom suggests, each frame was broken down and presented in a series of three or four textual and visual portions, or "chunks." It was believed that this change would help to direct students' attention to the information contained in the animated sequences by reducing the threat of distraction from other screen information, such as novel text. Results of the study showed differentiated learning effects for lessons con-

tained animation as compared to those containing static visuals or no visuals (Rieber, 1990-b). There is a need to validate whether this modification actually accounted for differentiated learning from animated displays by helping to increase students' selective attention to lesson information contained in the display. The first objective of this study was to investigate this issue.

In addition to evidence that animation can aid intentional learning, further research suggests that animation may also promote incidental learning. In a recent study, students effectively extracted incidental information about a specific application of Newton's second law contained in animated display and were subsequently able to use this information to solve problems (Rieber, in press). The study of incidental learning, though well-established in the general literature (see Klauer, 1984, for a review), is usually overlooked in the design of instruction based on systems approaches (Branson & Grow, 1987). Proponents of incidental learning assert the ability of the learner to elaborate upon the given instruction and to induce concepts and principles from the context. Past studies of incidental learning have typically indicated trade-offs between intentional and incidental learning. Faced with allocating limited cognitive processing abilities, students typically make gains on one kind of learning (e.g. intentional) at the expense of other kinds of learning (e.g. incidental). However, in the study by Rieber (in press), students were able to learn incidental information without any apparent sacrifices to intentional learning. The economical nature of spatial information in working memory may provide access to greater amounts of information when lesson information is presented in both verbal and visual forms (Gagné, 1985). One application of this finding, if it proves to be robust, is using incidental information learned in one lesson as an organizer for subsequent lessons where this information would be intentionally taught. The issue of whether this incidental learning result is replicable is questioned and is the basis for the second objective of this study.

In summary, there were two purposes to this study. First, the effects of visual grouping of lesson presentations containing animated and static visuals on learning were investigated. It was hypothesized that animated graphics presentations would facilitate learning more than static graphics, but only when presented in a grouped or "chunked" manner as this should significantly influence students to selectively attend to the relevant details contained in the animation. A secondary purpose was to replicate earlier findings that animated graphics promote incidental learning. It was hypothesized that students in lessons containing animated presentations would significantly outperform other students on measures of incidental learning as has been previously documented (Rieber, in press).

Method

Subjects

The subjects consisted of 39 fourth grade students from an urban public elementary school. Participation was voluntary with selection based on parent consent.

CBI Lesson Content

The CBI lesson, first developed for previous studies (Rieber, 1989; Rieber, 1990-b; Rieber, in press) but modified for the purposes of this study, described and explained Newton's laws of motion. The lesson was divided into two parts. Part one introduced students to Isaac Newton and his first law of motion (i.e. an object in motion tends to remain in motion and an object at rest tends to stay at rest). Part two provided applications of Newton's first law and introductions and applications of Newton's second law (i.e. force equals mass times acceleration). The lesson was designed and presented at an introductory level in the context of one-dimensional motion without friction and gravity.

Lesson Versions

Two levels of Visual Presentation (Static Graphic, Animated Graphic) were crossed with two levels of Visual Grouping (Grouped, Ungrouped).

Visual Presentation. In each Visual Presentation condition the lesson narrative was supplemented with either static or animated graphics. In the Static Graphics condition, forces were represented by a foot giving an object a kick, such as a ball or a concrete block. Motion and trajectory attributes were represented by arrows and path lines. The Animated Graphics condition also used the ball, block and foot symbols. However, the object was then animated to show the motion and trajectory resulting from the force applied to it. Both the static and animated visuals elaborated the textual information.

In addition to the information which was intentionally taught in both the static and animated graphic conditions, another application of Newton's second law — that dealing with the motion which results when the mass of an object varies — was *incidentally* demonstrated in the Animated Graphics condition. This law predicts that when two objects of different masses are both acted on by the same size force, the acceleration experienced by the object with larger mass is less. The computer animated a large "concrete block" moving very slowly across the computer screen after being kicked with the same size force which had just been

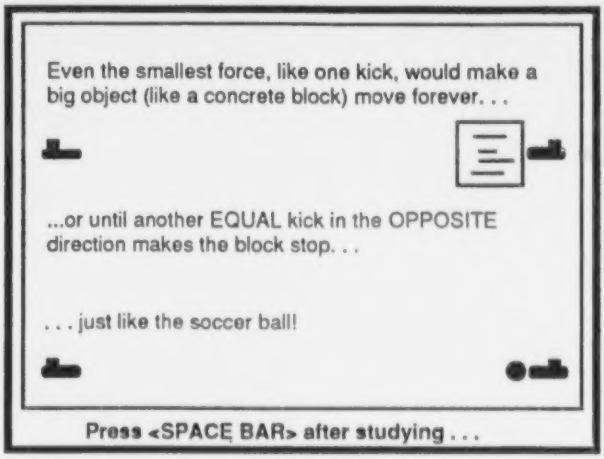


FIGURE 1. *Example of a computer screen which used animation to present intentional and incidental information. The "concrete block" and the "ball" were both kicked once. The animation depicted the ball's speed as dramatically greater than that of the block. Copyright 1991 by the American Psychological Association.*

applied to a small animated "soccer ball," similar to what is illustrated in Figure 1. The incidental information contained in the animation attributes was in the form of varying the *speed* of the two moving objects of different masses on the computer screen. No attempt was made to teach or explain why the block moved more slowly than the ball. By design, no incidental information was contained in the static visuals as no information related to "speed" was contained in the arrows or path lines.

Visual Grouping. The verbal (textual) and visual information in each lesson frame was presented to subjects in one of two ways: grouped and ungrouped. Each frame of instruction in each grouping condition contained exactly the same information formatted in the same way. The difference between the two groups was the way in which the information was presented to the subjects. In the ungrouped condition, as in most CBI, lesson information was presented to subjects one frame at a time as one continuous unit. Students were prompted to press the space bar when ready to view the next frame. In the grouped condition, each frame was presented to subjects as a series of three of four information groups, or "chunks," in order to cue subjects' attention to the animated visuals and to minimize screen distractions. Each subject was then prompted to press the space bar when ready to view the next chunk, as illustrated in Figure 2.

Dependent Measures

Posttest. The 24-item posttest measured two types of rule learning: intentional and incidental. Intentional learning is defined as learning those objectives which were directly taught in the lesson through the combination of verbal (text) and visual means. The intentional learning outcomes included applications of Newton's first law and a specific application of Newton's second law in which the mass of an object is held constant and the forces which act upon it are allowed to vary. Incidental learning is defined as learning those objectives which were not directly taught, but only implied through contextual cues provided in several of the animated visual displays. The incidental learning outcome was another application of Newton's second law in which the forces acting on objects are held constant and the mass of the objects is allowed to vary. Half of the intentional and incidental questions were presented in an all-verbal form and half contained accompanying visuals.

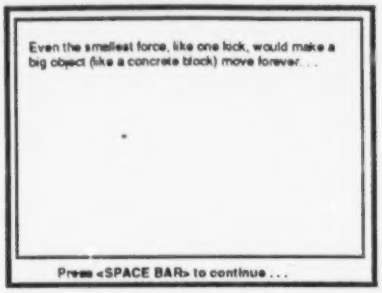
KR-20 reliability of all 24 questions was .86. Respective reliability coefficients and number of questions for each of the subscales were as follows: .78, 14 (Intentional); .90, 10 (Incidental).

Procedure

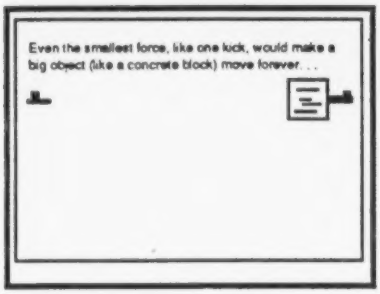
All instruction and testing was administered by computer. As students arrived at the computer lab they were randomly assigned to one of the treatment groups. After a group orientation to the lesson, students completed the lesson individually. Approximately 75 minutes was needed by students to complete the lesson and posttest.

Design

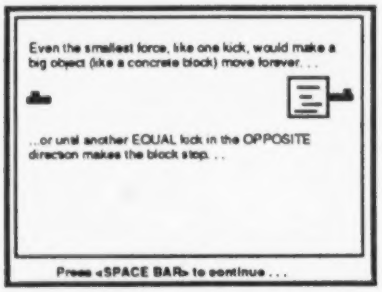
In this study a 2 X 2 X (2) factorial design was used. Two between-subjects factors (Visual Presentation,



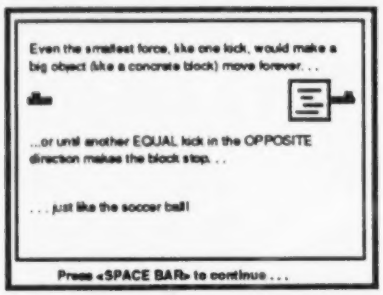
Frame chunk1: Text



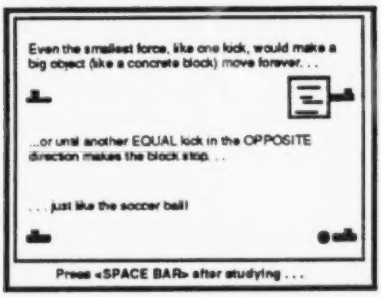
Frame chunk 2A: Animation sequence immediately followed by ...



... frame chunk 2B: Text



Frame chunk 3: Text



Frame chunk 4: Animation

FIGURE 2. *An example of how a single lesson frame was grouped into verbal and visual portions, or "chunks." Each student pressed the space bar when ready to view the next chunk.*

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TABLE 1. *Mean Percent Scores and Standard Deviations for the Posttest*

Visual Presentation	Visual Grouping		Learning Outcome: Intentional	Learning Outcome: Incidental
Animated Graphic	Grouped (n=10)	Mean	79.3	69.0
		SD	17.0	34.1
	Ungrouped (n=10)	Mean	59.3	54.0
		SD	29.7	31.3
Static Graphic	Grouped (n=9)	Mean	66.7	17.8
		SD	22.6	22.8
	Ungrouped (n=10)	Mean	71.4	32.0
		SD	16.8	30.1

Notes: SD-standard deviation; n-number of subjects

Visual Grouping) were crossed with one within-subjects factors (Learning Intent). The between-subjects factors consisted of two levels of Visual Presentation (Static Graphic, Animated Graphic) and two levels of Visual Grouping (Grouped, Ungrouped). The within-subjects factor consisted of two levels of Learning Intent (Intentional, Incidental). The within-subjects factor also served as the dependent measure. A mixed factor analysis of variance (ANOVA) was used to analyze the quantitative data.

Results

Percent means and standard deviations of student posttest scores are contained in Table 1. A significant interaction was found between Visual Presentation and Visual Grouping, $F(1,70)=5.08$, $p<.05$, $MS_e=697.71$. Follow-up analyses indicated that students in the Animated Grouped condition (mean=74.1%) performed significantly better on the posttest than students in either the Static Grouped (mean=42.2%) or Static Ungrouped (mean=51.7%) conditions, as shown in Figure 3. The Animated Ungrouped condition (mean=56.6%) was not significantly different from any of the other three conditions. These results support the first hypothesis of this study that students in the Animated Graphics condition would outperform those in the Static Graphics condition, but only when properly cued and guided to attend to the information contained in the animated display. Animated graphics presented continuously with other frame information were no more effective than either of the static graphics conditions. These results reflect the differences reported between the Rieber (1989) and Rieber (1990-b) studies.

A significant interaction was also found between Visual Presentation and Learning Intent, $F(1,70)=9.22$, $p<.01$, $MS_e=697.71$. Students in the Animated and Static Graphics conditions performed similarly on intentional learning (means=69.3% and 69.2%, respectively), however, students in the Animated Graphics condition (mean=61.5%) dramatically outperformed those in the static graphics condition (mean=25.3%) on incidental learning, as shown in Figure 4. As expected, these latter students performed at about the rate expected for guessing on incidental questions. This result supports the second hypothesis of this study which stated that students receiving animated demonstrations of incidental information would attend, understand, and retrieve this information when tested although no formal attempt was made to teach or explain the principle. This finding successfully replicates the incidental learning results reported by Rieber (in press).

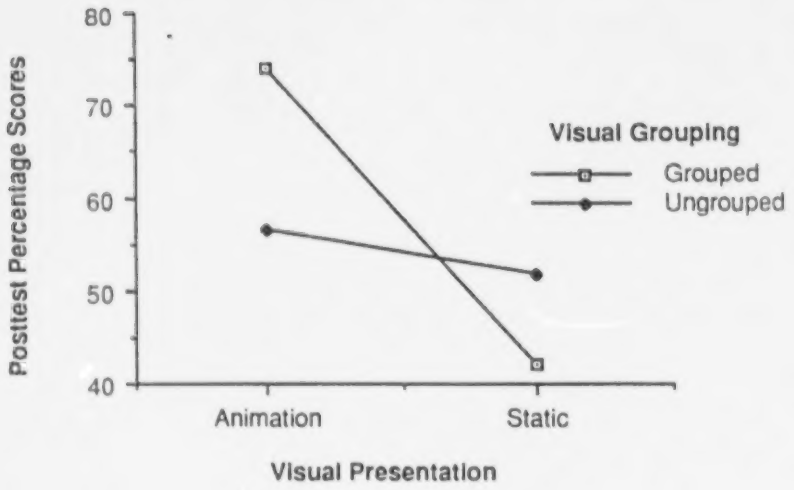

FIGURE 3. *Interaction between Visual Presentation and Visual Grouping.*

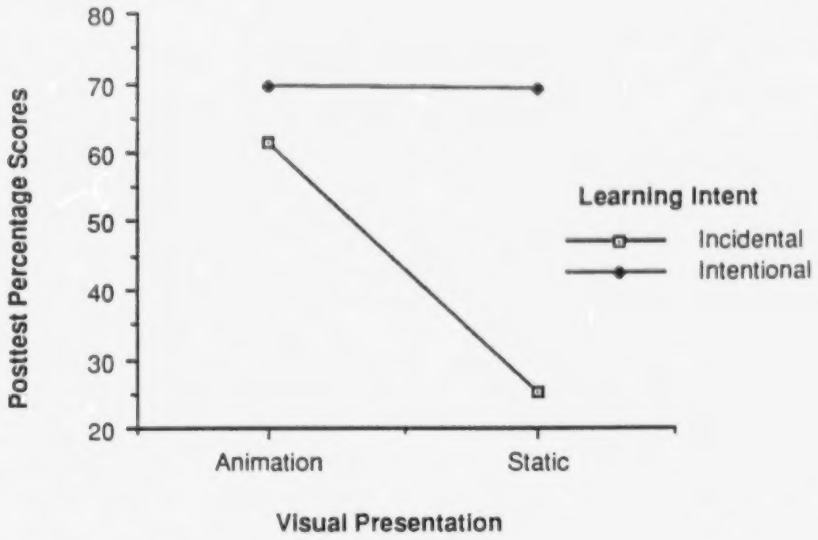

FIGURE 4. *Interaction between Visual Presentation and Learning Intent.*

Discussion

There were two purposes to this study — one primary and one secondary. The primary purpose was to investigate whether students' selective attention to animated information is influenced by the method in which it is presented. In this study, students in the Animated Grouped condition performed significantly better on the posttest than students in either of the Static Graphics conditions. In other words, animation was a significant aid to learning as compared to static graphics, but only when presented as part of a series of verbal and visual chunks. Students who were presented with lesson frames which contained static visuals were not influenced by the method of grouping.

These results were anticipated. Past research which has compared the use of animated and static visuals as adjunct presentation aids has indicated that animation's influence on learning, if any, are relatively subtle (e.g. Caraballo, 1985; King, 1975; Reed, 1985; Rigney & Lutz [Alesandrini], 1975). Perceptually, animated visuals offer two attributes beyond that of static visuals: motion and trajectory (i.e. direction of travel) (see Rieber, in press; and Rieber & Kini, 1991, for a more thorough description of the theoretical foundations of instructional applications of animated visuals). Therefore, learning from instructional tasks which require students to visualize the motion of objects along certain paths should be improved with appropriate applications of computer animation. It was hypothesized that animation would be effective when its attributes were congruent to the learning task *and* when presented to students in a manner that effectively cued their attention to the information contained in the animated visual. Past research has suggested that children do not necessarily know how to "read" an animated visual designed to illustrate an intellectual skill, perhaps because much of the animation they experience is meant to appeal to their affective domain, such as cartoons. In this study, a simple grouping strategy was used in the presentation of the computer lesson frames. Each frame was broken down into a series of three of four verbal and visual portions, or "chunks," which were presented individually to students. Students in these Grouped conditions had control over the pacing of these lesson frame chunks. The results of this study support the hypothesis that students attention to animation must be sufficiently cued and directed in order for potential learning effects derived from animation to be realized. It is suggested that the grouping strategy used here is but one example of a possible attention focusing device that might be used.

Adjunct static graphics would not be expected to be influenced by the grouping strategy used here given the fact that students had as much time as they needed to view each lesson frame. Since a static graphic, by definition, does not change over time, students had sufficient opportunity to study these visuals and their relationship to the lesson text. Animated visuals, on the other hand, demand temporal considerations. If students do not educe the information they contain, either because they did not understand the message or did not attend to the sequence, they may not have another opportunity to view the sequence and correct their learning deficiency, as was the case in this study. Many alternative strategies which help students attend to the information undoubtedly exist beyond the simple grouping strategy used here. For example, simply providing students with the opportunity to repeat an animated sequence may be effective, assuming, of course, that students are monitoring their comprehension sufficiently to know that they did not comprehend the animated sequence and that the option to repeat exists.

Much of what is known about instructional visuals comes from the pool of static visual research. Recent reviews suggest a variety of guidelines and conditions under which static visuals contribute to learning (see Alesandrini, 1984; Dwyer, 1978; Kobayashi, 1986; Levie & Lentz, 1982; Levin, Anglin, & Carney, 1987). Among the most important groundrules guiding the use of visuals is congruency between presentation and task variables (Levin & Lesgold, 1978). It is suggested that animated visuals represent a subset of instructional visuals and therefore represent extensions of the empirical and theoretical base of static visuals (such as that provided in the dual-coding hypothesis offered by Paivio, 1986). The results of this study suggest an additional important groundrule for the successful application of animated visuals in instruction: students' attention must be adequately cued to the information contained in an animated visuals and special consideration needs to be taken to avoid having their attention distracted away from the animation, even if the animation is well-designed in all other ways, otherwise no learning may occur.

The second goal of this study was to replicate earlier findings that elementary school students are able to extract incidental information contained in an animated visual. Besides providing a visual elaboration of the intentional learning outcomes, the animated sequences also demonstrated incidentally an application of Newton's second law where the masses of two objects varied, but the forces acting on them remained constant. The incidental information was represented by the relative motion of screen objects: an animated "concrete block" moved obviously slower than a

"soccer ball" after equal size forces were applied to each. The students in the Animated Graphics conditions were apparently able to attend to, learn, and apply a sophisticated science principle without any apparent sacrifice to intentional learning. These results successfully replicate similar and earlier findings (Rieber, in press).

In conclusion, this study has demonstrated the fragile influence that animated visuals exert on learning. Learning from apparently well-designed animated visuals can be subverted when students' attention is not sharply focused on the relevant information contained in an animated sequence. Designers and developers must be careful not to confuse the dramatic visual effects of animation with its related effects on learning. Young children especially appear to need external prompting or cueing in order to effectively learn from animated visuals. However, learning can occur when students are focused on an animated visual. The replicated findings that students can learn and apply a scientific rule presented incidentally by an animated visuals offer a glimpse of the potential of animation in learning environments. The incidental information contained in the animation was simple and easily discernible by students, such that they did not even need explicit guidance to appropriately learn and apply the information. Several directions for future research and developmental work are suggested. More research is needed to clarify and validate the grouping strategy used in this study as well as other potentially effective cueing strategies. Much development work is needed to appropriately exploit the incidental learning gains suggested by the use of animated visuals, such as using this incidental learning as a bridge to intentional learning in subsequent lessons.

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